Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

2 St 2
op 2

STATION PAPER NO. 15 MARCH 1954

RED ROT OF PONDEROSA PINE IN THE SOUTHWEST

Stuart R. Andrews
Forest Pathologist

LIBRARY
RECEIVED
MAR 7 1961
U. S. DEPT. OF AGRICULTURE

U. S. DEPARTMENT OF AGRICULTURE
Forest Service
ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION
Fort Collins, Colorado

Raymond Price, Director

INTRODUCTION

In Arizona and New Mexico red rot, caused by the fungus Polyporus anceps, is the only heart rot of economic importance in ponderosa pine (Pinus ponderosa). There is little evidence that it attacks living trees of other species, although it is abundant on slash of many conifers throughout the country. Its prevalence in the ponderosa pine stands of the Southwest may be explained in part by climatic conditions that favor the rapid development and spread of the decay. It is also possible that the Rocky Mountain variety of this pine is particularly susceptible to attack.

In addition to red rot, two other white pocket rots occasionally attack living ponderosa pine in this region. One of these, red ring rot, caused by Fomes pini, has been found in overmature trees growing in mixture with Douglas-fir in the Lincoln National Forest, but has not been observed elsewhere. Another, red root and butt rot, caused by Polyporus circinatus, occasionally appears at stump cuts and may extend six to eight feet into butt logs. Several brown cubical rots (especially red brown butt rot, caused by Polyporus schweinitzii, brown trunk rot caused by Fomes officinalis, and brown crumbly rot caused by Fomes pinicola) are sometimes common in overmature stands. Observations indicate that probably none of these decays will be of much importance in second-growth sawtimber. They are readily distinguished from red rot on the basis of the appearance of decayed wood or the portion of the tree attacked. All are fully described in standard textbooks on Forest Pathology.

Observations, from 1913 to 1917, by W. H. Long form the basis for much of our present knowledge of red rot. He reported that the rot was associated with overmaturity and stated that it would be unimportant after the old-growth timber had been cut and the length of the rotation reduced to 200 years or less. In 1934, however, Long reported that he had found many young stands in which a surprising number of the trees had red rot in the lower branches. He believed that this condition was indicative of serious future losses in second-growth sawtimber.

Since 1934, considerable information has been released on red rot in second-growth, but it may not be available to all foresters now engaged in timber management in the region. Furthermore, while this rot is readily recognized in logs cut from mature and overmature trees, branch decay or potential heart rot in immature stands is unfamiliar to many individuals. There are no entirely reliable external signs of potential or actual decay in young or old trees, and repeated emphasis of this point probably has led to a tendency to leave it to "the experts" until satisfactory criteria have been developed. Although heart rot is already established in many of the young blackjacks being cut under the modified selection system, the amounts are small and decay pockets often do not show at

either end of even short (12-foot) logs, and volume losses apparently are negligible. However, similar heart rot infections in the residual stand probably will have 75-100 years to develop before a harvest cutting is made and can be expected to result in significant losses.

The importance of red rot in second-growth ponderosa pine under management cannot be determined accurately until some of the present immature stands have attained cutting age. In the meantime, it is planned to accumulate data on heart rot in normally stocked stands now 100 and 150 years old; although it is recognized that these stands developed under conditions that differ widely from those existing in intensively managed stands. Available estimates of future losses are based on the combined results of a few defect studies made in conjunction with timber sales, and an intensive survey of immature stands during which representative infected trees were dissected. Ordinarily, trees removed in timber sales do not provide a very satisfactory sample of heart rot. In the mature and overmature age classes, a large proportion of the cut is composed of trees that were suppressed during early life, the more vigorous individuals having dropped out as a result of lightning strikes, windthrow, and the action of other agencies. In the immature age classes, the reverse is often the case as the cut is confined to limby, open-grown, or otherwise undesirable trees. Furthermore, the practice of cutting young trees into a single long log instead of several short logs tends to leave some heart rot unexposed and unscaled.

Recent developments in timber management and forest utilization justify an up-to-date discussion of the red rot problem in second-growth timber. Improvement measures such as pruning crop trees and thinning dense stands (contingent on the development of a market for the products of thinnings) suggest possibilities for reducing red rot losses that were formerly considered uneconomical. On the other hand, should a demand develop for post and pole material removed in thinnings, it is entirely possible that rotten knots or small amounts of red rot in the heartwood will be the basis for culling otherwise desirable piece products, unless it can be demonstrated that volume losses are negligible and strength is unimpaired.

DESCRIPTION OF RED ROT INFECTION

The red rot fungus (P. anceps) is adapted to the environmental conditions of the ponderosa pine type in the Southwest. In the laboratory, the fungus grows well over a wide range of temperature but makes most rapid growth at 85°-95° Fahrenheit, a considerably higher optimum than has been observed for most heartwood rotting fungi. Such temperatures often prevail in the forest during the summer rainy season when new infections are getting started. The ability of the fungus to penetrate the pitchy knots of ponderosa pine distinguishes it from other branch decay fungi found on this species, all of which become arrested or die after destroying the outer portion of dead branches.

Source and manner of infection of living trees

The fungus fruits abundantly only on dead material in close contact with the ground, although it sometimes develops on standing snags and rarely on dead branches of living trees. Fruiting bodies (Fig. 1) appear about four years after such material is infected, and they continue to develop annually for about six years. Most of them mature and shed their spores during the summer rainy season. The airborne spores lodge in small openings in the bark of dead branches and probably germinate at once if moisture conditions are favorable.

Development of infections

Following spore germination, the red rot fungus develops a pad of mycelium between the bark and wood from which the wood of the branch itself is invaded. The pad also tends to keep the bark intact, thus reducing fluctuations in the moisture content of the wood that would inhibit decay. Although infection often takes place in distal portions of a branch, rapid extension of the mycelial pad leads to establishment of the rot in close proximity to the trunk. The outer portion of a branch, which is mainly sapwood, is rapidly decayed. When the rot reaches the pitchy branch base it concentrates into slender columns. The columns penetrate the knot, some through the pith cavity, and others through the wood. Figures 2 and 3, A show rot in a dead branch and a knot. Eventually the rot columns reach the heartwood of the trunk and heart rot develops (Fig. 3, B). Failure of some infections to reach the trunk heartwood may result from the activity of other decay fungi, breakage of the branch or loss of bark, the effect of fires, and possibly from inherent differences in races of the pine or the fungus.

Susceptibility of branches and trees to infection

Branches are susceptible to attack by the red rot fungus from the time they have dead wood until they have been dead for about 20 years, provided they have retained their bark. After appreciable amounts of bark slough off or the main branches are broken, they are no longer susceptible to infection probably because the moisture content of the wood falls below that required by the fungus. To serve as entrance points, branches need not contain heartwood. Large dead branches (basal d.i.b. larger than 1 inch) are about ten times more susceptible to infection than small dead branches (1/2-1 inch). Infections do not occur in sapwood exposed by wounding or on the surface of knots left after pruning.

Living branches are sometimes infected when the red rot fungus attacks dead secondaries, and the rot may eventually extend into the trunk through the branch heartwood, if present, or, in rare instances, through the living sapwood in truly parasitic action. Except in large and long-lived branches, however, these infections make little progress before the branches die and new infections occur closer to the trunk.

Young ponderosa pine can be attacked by the red rot fungus any time after it has one or more susceptible branches. The probability that a tree is infected depends on the number and size of its dead branches and the length of time that these branches have been subject to spore showers. It is possible that dead branches may not be exposed to infection during the susceptible period because of the absence of fruit bodies in some localities. For practical purposes, however, it has been assumed that the amount and distribution of infectious material is more or less constant.

APPEARANCE OF RED ROT

Like most other wood decays, red rot can be considered as having two stages, viz., the incipient stage in which the wood is discolored but apparently not weakened, and the advanced stage in which disintegration of the wood is evident. Although the appearance of decay, whether in the incipient or the advanced stage, is about the same in both dead sapwood and heartwood, the manner in which the fungus invades the wood leads to differences in the overall aspect of sap rot and heart rot.

Sap rot

In sap rot of dead material innumerable hyphae from the overlying mycelial pad invade the wood in a radial direction. Depending upon the size of the pad, a large proportion of the wood may be simultaneously invaded even in culled logs. Inasmuch as dead sapwood is highly susceptible to decay, penetration toward the center is rapid. The result is that practically all of the wood will show incipient decay at the same time, whereas within a year the same wood will uniformly show advanced decay. Sap rot is illustrated in Figure 4, which shows a portion of a decayed dead branch. The incipient stage of decay in the upper half of the branch is revealed only by a reddish-brown discoloration of the wood. The advanced stage in the lower half is characterized by small white pockets running parallel to the grain. The white lines between bark and wood are the edges of the mycelial pad. The cross section of the branch illustrates the uniformity of decay following radial invasion of the wood from the mycelial pad.

Heart rot

In heart rot the wood is invaded in a longitudinal direction by a slender column of decay from an infected knot. The decay continues to develop rapidly in this direction while radial spread is slow. Because of this difference in the rates of directional development, both the incipient and advanced stages may occur in apparently isolated pockets of varying size. Heart rot is illustrated in Figure 5, which shows the incipient stage (A) and the advanced stage (B) on the ends of logs. The appearance of both stages in

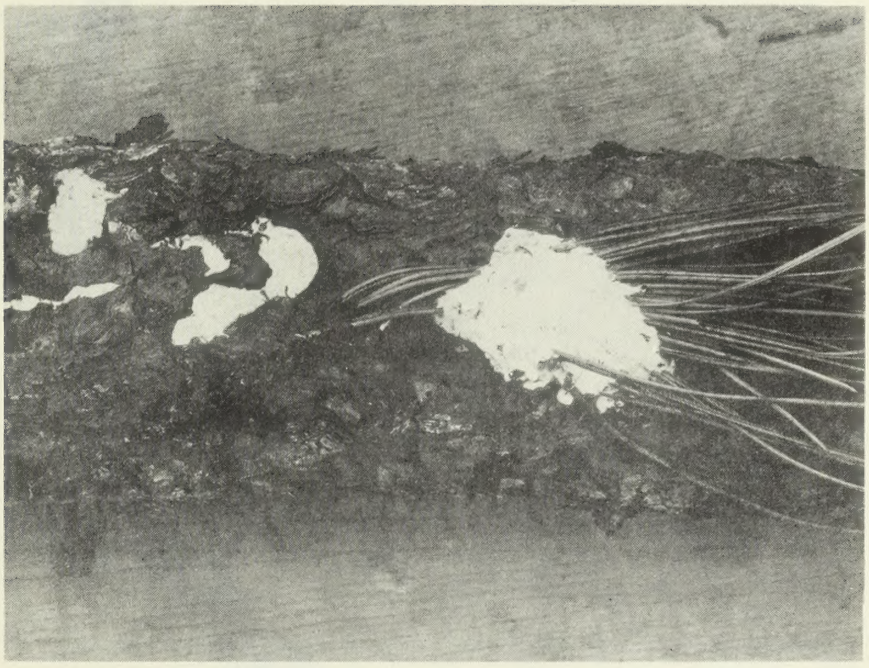

Figure 1.--Annual fruiting bodies of the red rot fungus (Polyporus anceps) on the underside of a detached large dead branch. White when fresh, some fruiting bodies darken when they dry out. They are attacked by several species of insects and may deteriorate rapidly.

Figure 2.--Red rot infected dead branch. Infection apparently occurred at point marked by arrow. The infection had reached the pitchy base of the branch where it had concentrated into slender, highly pigmented columns of decay.

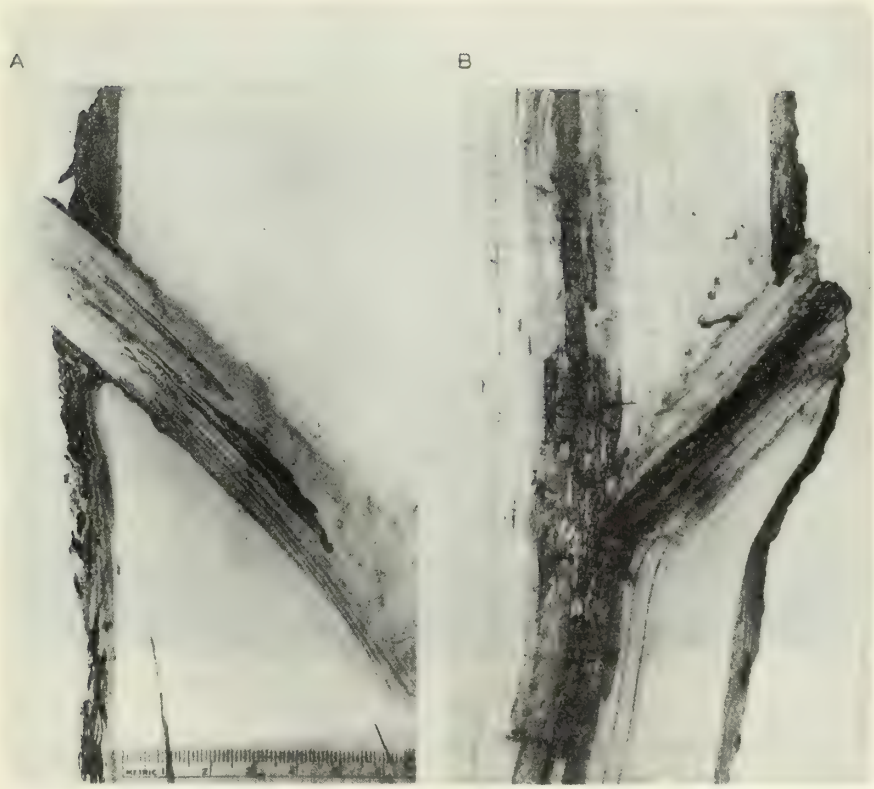

Figure 3.--Red rot from an infected branch eventually enters the trunk. (A) Rot extending about 2-1/2 inches into the tight knot. The central position of the longest column suggests that the rot traveled more rapidly through the pith than in the knot wood. (B) Rot that followed the pith of the knot into the heartwood of the trunk and developed into heart rot.

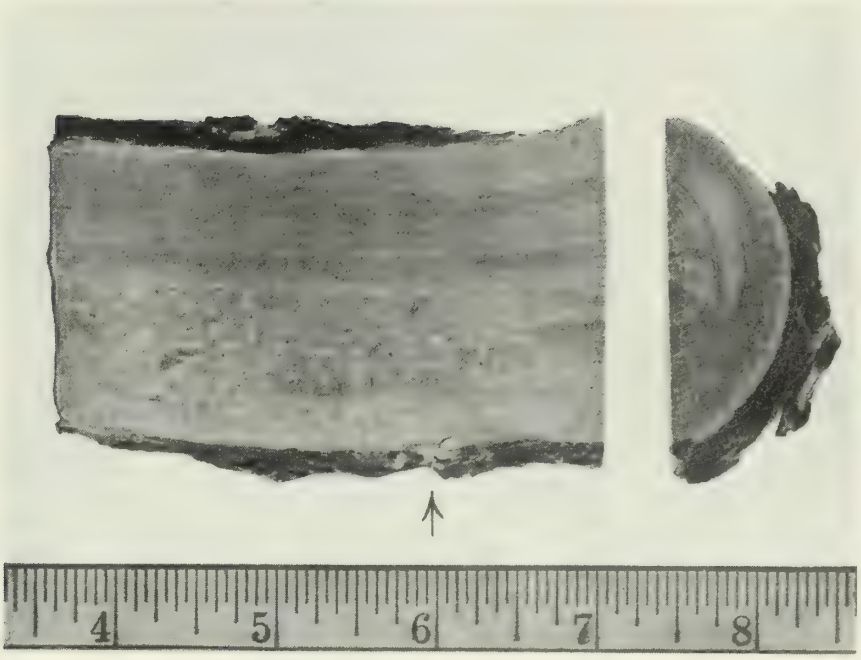

Figure 4.--Red rot. Sap rot in longitudinal and cross sections of a branch that was inoculated with the red rot fungus at point indicated by arrow. The incipient stage of decay in the upper half of the branch is revealed only by a reddish-brown discoloration of the wood, in contrast to the lighter color of sound wood near the right end of the longitudinal section. The advanced stage in the lower half is characterized by small white pockets running parallel to the grain. The white lines between bark and wood of the upper half are the edges of the mycelial pad. The cross section of the branch illustrates the uniformity of the decay following radial invasion of the wood from the mycelial pad.

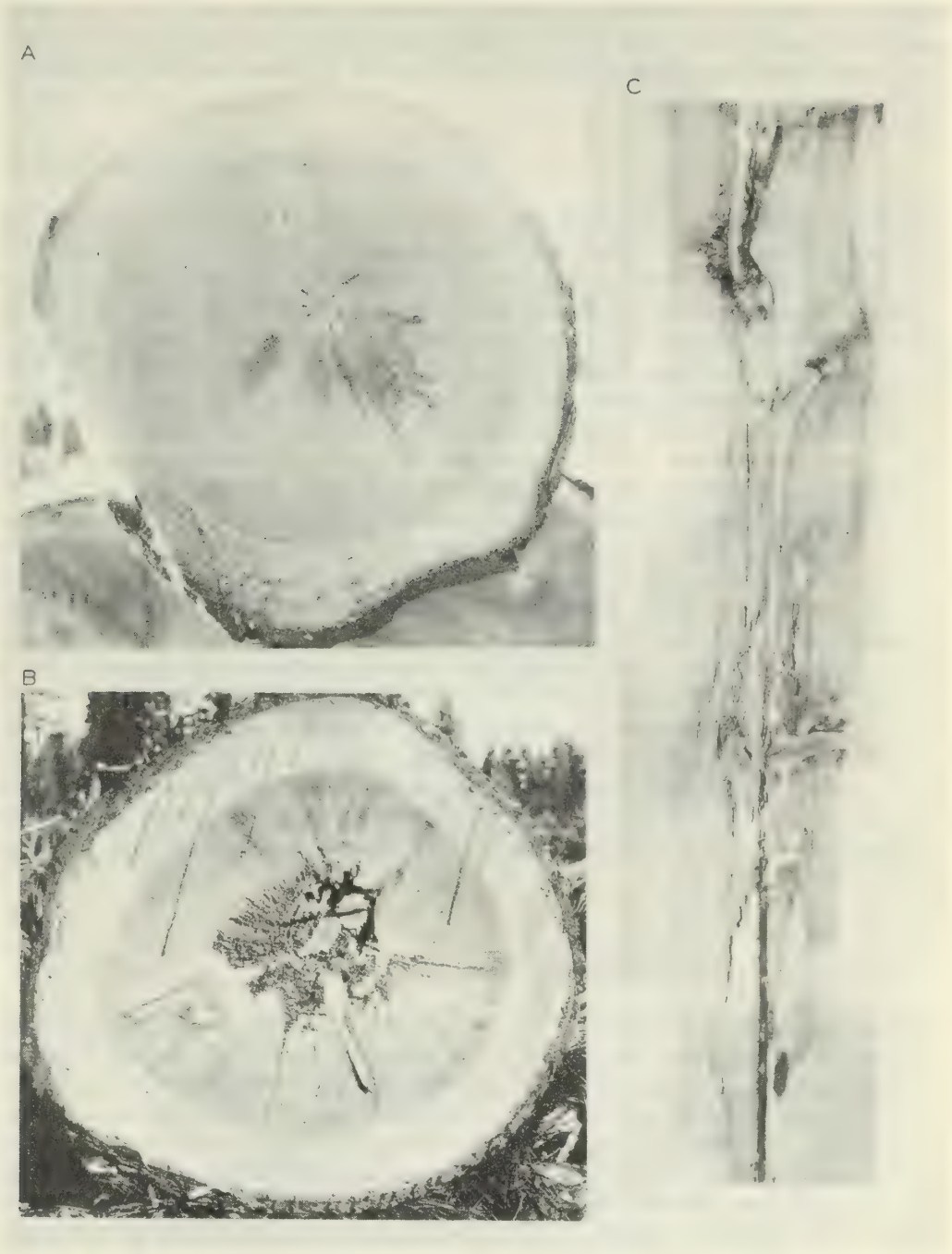

Figure 5.--Heart rot. Red rot in the heartwood of an over-mature tree: (A), the incipient and (B), the advanced stages at the end of a sawlog, and (C), both stages on the surface of a board.

longitudinal section, or on the surface of a board, is shown in Figure 5, C. The common discontinuous appearance of the incipient stage in longitudinal section results from the fact that the decay follows the spiral grain of the wood and is only intermittently exposed by the sawcut.

Recognition of infection

Familiarity with the appearance of the decay in dead branches or at pruning cuts may be increasingly important in connection with thinning and pruning operations in second-growth stands. Red rot in the pruned or broken outer portions of dead branches can be easily distinguished from decays caused by two other white-rot fungi that have never been found in the heartwood of living trees. In both the incipient and the advanced stages, red rot infection is characterized by the continuous white mycelial pad (Fig. 4) that binds the bark so tightly to the wood that the bark cannot be peeled from the branch without particles of wood adhering. Of the other two branch decay fungi, Fomes tenuis forms a brown mycelial pad between the bark and wood, and Polyporus abietinus a white to brownish netlike pad, neither of which binds the bark to the wood. Since the wood of knots is similar to heartwood, the best indications of red rot infection are the deeply discolored pockets of decay that show on the sawcut of pruned rotten branches. No other branch decay fungus is able to penetrate pitchy branch bases to any extent and duplicate the typical appearance of red rot. Especially in the case of long-standing infections in the lower trunks of young trees, only short weathered stubs still protrude and the cross-sectional appearance of decay is the only means for recognizing red rot.

RED ROT IN IMMATURE STANDS

An intensive survey of red rot was made in immature stands during 1938 and 1939. Butt-log infection in standing trees was determined on a large number of sample plots by pruning and examining all dead branches and branch stubs to a maximum height of 17 feet above ground. Trees were classified as infected if they had one or more rotten branches below that height. The amount of heart rot in the trees at the time of the survey was also determined by dissecting a representative sample of the infected trees on each plot. Results of the survey data, which were published in 1943, indicated that in stands 41-100 years of age red rot infection was directly correlated with the size and number of dead branches and size of trees, and inversely correlated with stand density. In younger stands, infection was usually negligible and poorly related to these factors because the dead branches had been susceptible to infection but a few years. Infection did not increase directly with age in 41- to 100-year-old stands. This was to be expected

inasmuch as the criterion of infection was the presence of a single rotten branch below the 17-foot point. It was obvious, however, that the average number of infected branches per tree tended to increase with age until all dead branches below 17 feet either had been attacked or had lost their susceptibility to decay. Furthermore, it was apparent that the proportion of infections that had developed into heart rot and the amount of heart rot had increased directly with age.

The relationship of infection and associated heart rot to the above-mentioned features of trees and stands is best illustrated by composite data from 18 plots in 41- to 60-year-old stands in the Sitgreaves National Forest. Table 1 shows some of the characteristics of three stand density classes into which the data were divided. Both infection and heart rot were more prevalent on a percentage basis in open stands than in the other two density classes.

Table 1.--Descriptive data for three density classes. Averages for 18 plots in 41- to 60-year-old stands in the Sitgreaves National Forest

Density (Trees per 0.1 acre) Class	Mean	Basis: Plots	Average Age	Western red rot below 17 feet. Percentage of all trees with: One or more infected branches	Heart rot[1]
(No.)	(No.)	(No.)	(Yrs.)	(Pct.)	(Pct.)
Open (75 or less)	41	3	50	53	10
Medium (76-150)	127	8	50	23	8
Dense (151 or more)	207	7	52	19	7

[1] Dissection was limited to a mechanically selected sample of infected trees on each plot. It was assumed that the amount of heart rot found in these trees was indicative of that present in all trees. Thus, in the open class, since 53 percent of the trees were infected and 19 percent of the dissected trees had heart rot, 10 percent of all trees in the class probably had heart rot (19 percent of 53 percent).

Infection

Figure 6, A, is a bar diagram showing the average number of infected and uninfected trees in the three density classes by 2-inch diameter classes. This is supplemented by Figure 6, B, showing the percentage infection for the same classes, as well as the percentage of trees with one or more large dead branches.

In addition to showing the close relationship between red rot infection and tree and branch size (the latter expressed as the percentage of trees with one or more large dead branches in Figure 6, B) in stands of approximately the same age, the figure indicates that:

(1) The denser stands contained more infected trees per acre than the open stands. Over a long period, however, mortality proportional to the relative number of infected and uninfected trees present will more than offset this. Furthermore, an increase in butt log infection is more likely to occur in the open stands, where crowns recede more slowly, as additional large branches below the 17-foot point die and become susceptible to decay.

(2) On a percentage basis, red rot infection was higher in open stands because only a few trees were uninfected. The denser stands contained a large number of small-branched and consequently uninfected trees.

(3) Regardless of the density of 41- to 60-year-old stands, infection percentages were high in trees 8 inches d.b.h. and larger.

Associated heart rot

The volume of heart rot in 41- to 60-year-old stands is insignificant regardless of whether it is measured in board feet or cubic feet. For purposes of analysis, length is therefore considered the most satisfactory measurement of heart rot in immature stands.

The average length of rot columns in the 16 dissected trees with heart rot was about one-half a foot and 82 percent of the columns were less than six-tenths of a foot. Because of the limited number of trees involved, no comparison was made of the length of heart rot in the three density classes, although there is some indication that length is greater in open than in dense stands. This is in accord with the relationship between heart rot and

tree size as given in Table 2, which shows that not only the percentage of trees with heart rot, but also the length, tended to increase directly with d.b.h.

Table 2.--Relationship between heart rot and d.b.h. on 18 plots in 41- to 60-year-old stands in the Sitgreaves National Forest

D.b.h. Class	Basis - Trees: Pruned	Basis - Trees: Dissected	Heart Rot: Percentage of all trees 1/	Heart Rot: Average length of columns per tree with heart rot
(in.)	(no.)	(no.)	(pct.)	(ft.)
3	7298	2	0.6	0.25
4-5	11590	10	6.2	0.16
6-7	4995	22	11.9	0.68
8-9	1682	15	8.9	0.96
10-11	283	6	12.5	1.38
12-13	35	0	-	-

1/ Dissection was limited to a mechanically selected sample of infected trees on each plot. It was assumed that the amount of heart rot found in these trees was indicative of that present in all trees. Thus, in the open class, since 53 percent of the trees were infected and 19 percent of the dissected trees had heart rot, 10 percent of all trees in the class probably had heart rot (19 percent of 53 percent).

A few unpruned infected trees were dissected adjacent to four of the 18 Sitgreaves plots in 1949. These trees were comparable with respect to age, size, and amount of infection to those cut on the plots in 1939. Heart rot was found in 6 of the 8 trees dissected in contrast to only one of the nine studied on the four plots in 1939. Heart rot was, therefore, about seven times more prevalent in the 1949 sample. The average length of the decay columns per tree with heart rot was about 1-6/10 feet as compared to one-tenth of a foot in the single tree affected in 1939. Although too few trees were dissected to provide an adequate sample, this suggests that heart rot increased about 1-1/2 feet during the 10 years following the original dissection study. These results may be indicative of rapid heart-rot development in young stands and if this rate is maintained the average length of decay columns in 16-foot butt logs with heart rot might be about 15 feet when trees are cut at an age of 150 years.

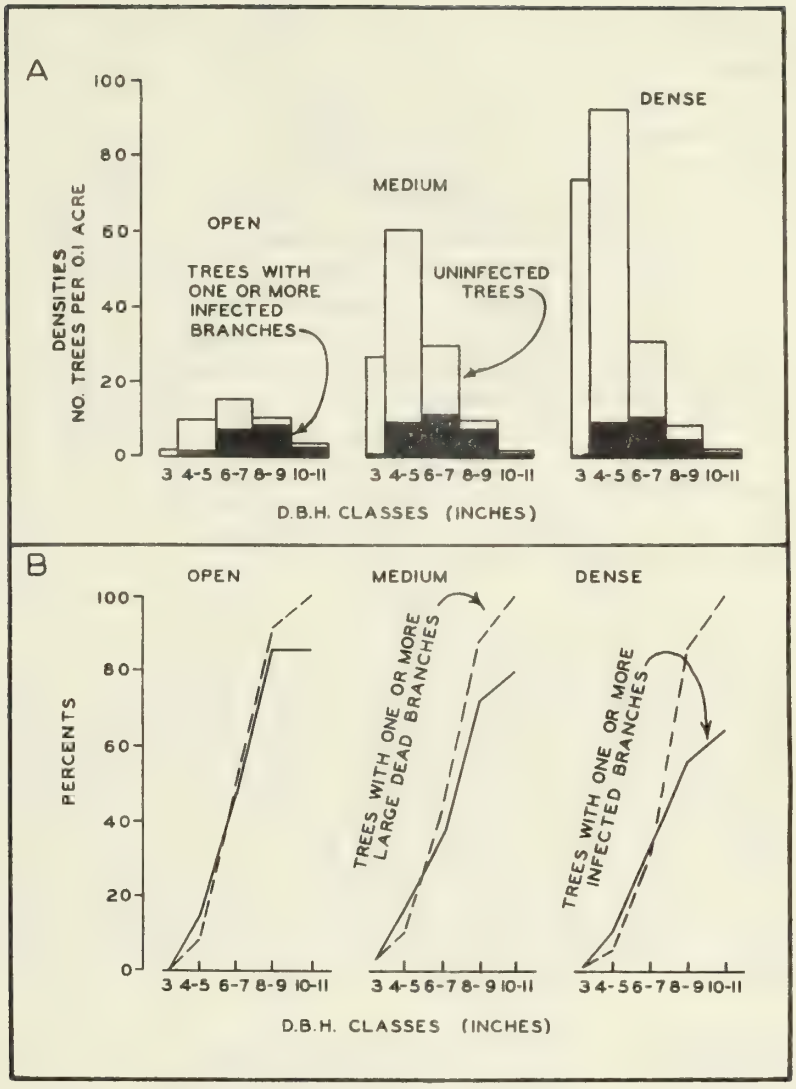

Figure 6.--Relationship of red rot infection to d.b.h. in three density classes. Averages for 18 plots in 41 to 60-year-old stands in the Sitgreaves National Forest. (A), Stand table in the form of a bar diagram, showing average number of infected and uninfected trees per one-tenth acre. (B), Infection shown in (A), in terms of percentages as compared to percentages of trees with one or more large (basal d.i.b. larger than 1 inch) dead branches.

RED ROT IN MERCHANTABLE TREES

Data on heart rot collected during the second cutting of the Wing Mountain Unit of the Fort Valley Experimental Forest in 1939 provide some indication of what may be expected in the way of volume losses, if the present immature stands are harvested for sawtimber at age 150 (141-160 years), although they have obvious limitations as pointed out at the end of this discussion. About 24 percent of the 1003 trees cut in this age class had scaleable heart rot in the butt logs, and deductions for the rot amounted to 3.4 percent of the gross butt-log scale. An additional 5 percent of the trees had heart rot above the butt log. Rot deductions amounted to 4.7 percent of the total gross merchantable volume for the age class. Butt logs, containing 54 percent of the total volume, accounted for 39 percent of the rot volume. Inasmuch as a mill-scale study was not made in conjunction with the logging study, no estimates of the volume of hidden decay could be made. Presumably, however, if this age class is comparable to present immature stands, an appreciable amount of western red rot in butt logs did not show at either cut. It is possible that the scale of visible rot resulted in a large enough overrun to compensate for that which was hidden, but this cannot be determined except by a defect study in which logs are opened up on the ground or traced through the mill.

The relationship of heart rot to tree size in the 150-year-age class is shown in Figure 7, A and B. From Figure 7, A, it is apparent that the percentage of gross volumes deducted for decay showed only minor fluctuations above 18 inches. The decrease in the occurrence of heart rot above 24 inches d.b.h. is explained in part by the fact that a high proportion of the larger trees were open grown and had large living branches extending almost to the ground. In such trees there had been little opportunity for infection and heart rot to develop. Figure 7, B, shows that heart-rot volumes increased directly with d.b.h., but at only about the same rate as gross volumes, with the result that the percentage of gross volumes decayed remained more or less constant.

These data appear to agree fairly well with the results of dissection studies in young stands, but certain limitations in application are obvious. First, the rot volumes found in the Wing Mountain Unit may not be representative of the region as a whole. Second, like other defect studies, information on decay was derived only from trees that were cut and nothing was learned about the condition of residual trees. While for most sizes this may not be a serious factor, at the lower and upper extremities of the d.b.h. range, marking policies tended to remove abnormal trees. Finally, little is known concerning the early history of the 150-year-age class. Presumably, it grew up under conditions that will not maintain during the lifetime of the present immature stands that are under intensive management. For example, the fire history of the Wing Mountain Unit suggests that this age class may have been subjected to a number of surface fires that killed some trees and protected others against trunk infection by charring lower branches.

Pruning

It is obvious that pruning protects young trees from red rot by eliminating branch infections that have not entered the trunk, and also by removing many uninfected but susceptible branches that might serve as entrance points in the future. For many years it was felt that pruning might also arrest growth or result in the death of the red rot fungus in some trunk infections, particularly those that were still limited to the outer portions of knots. Preliminary tests of this effect of pruning were sufficiently indicative to warrant an intensive study on a number of the red rot plots in 1949, the results of which are given in an article that was published in the January 1954 issue of the Journal of Forestry. None of the trees studied were less than 41 or more than 70 years old. Preliminary analyses indicated that the effect of age could be demonstrated best by using two 15-year-age class, viz: 41-55 years and 56-70 years, which are referred to as the 50- and 60-year classes, respectively, in the following discussion. Despite the different class limits, the results as summarized below are applicable to the 41- to 60-year-old stands of the Sitgreaves.

(1) Dissection study. Heart rot developed much more slowly in the 10 years following pruning in 50-year-old stands than in 60-year-old stands. In the former, although the proportion of infections that had developed into heart rot was twice as great in 1949 as in 1939, the average length of the columns remained about the same. In the latter stands, the proportion of heart-rot infections was three times greater in 1949 than in 1939, and the average length of the columns indicated an increase of about 1 foot per decade.

(2) Laboratory tests. In the 50-year-age class 19 percent of 31 red rot infections exposed by pruning were active and were either already in the heartwood or probably would have developed into heart rot within a few years. In the 60-year-age class 54 percent of 69 infections were of this type. In contrast to this, 73 percent of 30 infections in unpruned branches in the 50-year class and 80 percent of 41 in the 60-year class were active.

(3) Conclusions. It was concluded that although some infections became arrested naturally, pruning results in the death of the red rot fungus in an appreciable proportion of infections that have entered the trunk, in both 50- and 60-year-old stands, but that it is considerably more effective in the former age class. Red rot can be markedly reduced, therefore, by pruning according to existing silvicultural instructions in stands less than 60 years old. The earlier pruning is started, the more

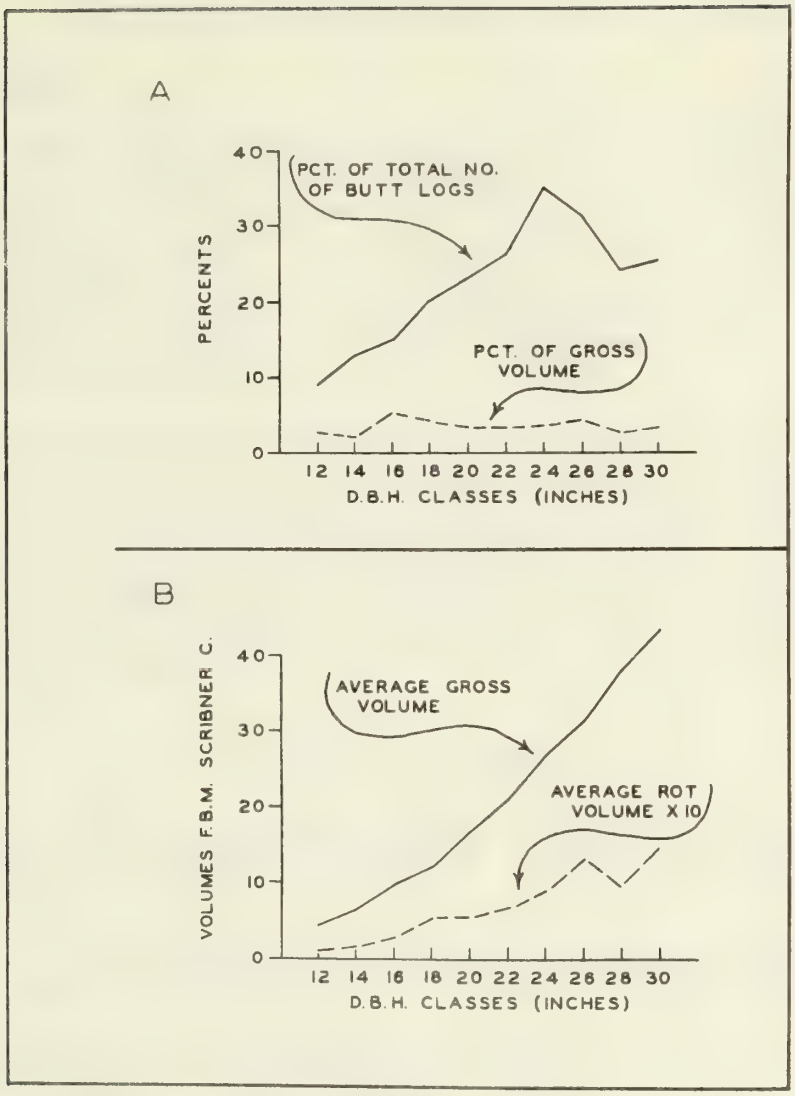

Figure 7.--Relationship between scaleable red rot in butt logs and d.b.h. in the 150 (141 to 160)-year-age class. Based on 1003 trees cut on the Wing Mountain Unit of the Fort Valley Experimental Forest in 1939. (A), Percentage of butt logs with rot and percentage of gross volumes deducted for this rot. (B), Average gross volumes and average rot volume times ten.

complete will be the protection against red rot. When less than the standard 17 feet of the trunk can be pruned in a single operation, subsequent treatments should be spaced 10 years apart for maximum results.

Thinning

No studies have been made in this region on the effect of thinning on red rot because of the widespread use of the crop-tree method in stand-improvement operations. Studies in the Black Hills of South Dakota during 1935-37 indicated, however, that thinning reduced the prevalence of red rot in young stands (less than 80 years old) even though attempts to discriminate against infected trees were indirect, simply by favoring fine-limbed codominants and intermediates over coarse-limbed dominants or wolf trees.

Should thinning replace the crop-tree method in this region, the Black Hills' findings would be generally applicable except that red rot is usually well established at an earlier age in the Southwest, and some practical means of discriminating against infected trees should be developed for use in stands older than 60 years of age. In younger stands, otherwise desirable infected trees need not be discriminated against during thinnings provided they will be pruned by the time they are 60 years old.

Suggested References

Andrews, Stuart R. Effect of pruning on western red rot in young ponderosa pine in the Southwest. Jour. Forestry 52: 33-38. 1953.

_____ and Lake S. Gill. Western red rot in immature ponderosa pine in the Southwest. Jour. Forestry 41: 565-573. 1943.

Boyce, John Shaw. Forest Pathology 2d ed. XI, 550 pp. Mc-Graw-Hill Book Co., Inc. New York. 1948.

Chapel, William L. Unmerchantability in second cut ponderosa pine. Jour. Forestry 40: 45-48. 1942.

Long, W. H. A preliminary report on the occurrence of western red rot in ponderosa pine. U. S. Dept. Agr. (professional paper) Bull. 490, 8 pp. 1917.

Pearson, G. A. Management of ponderosa pine in the Southwest. Agr. Monograph No. 6, U. S. Dept. Agr., Forest Service. 218 pp. 1950.